AP Computer Science Principles' Impact on the Landscape of High School Computer Science using Maryland as a Model

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ABSTRACT

The introduction of the Advanced Placement (AP) Computer Science Principles course changed the high school computer science (CS) landscape in the United States. For the first time an AP course was designed to broaden participation in computing and attract all students as opposed to being designed to challenge the highest performing students. The goal was to design a rigorous and comprehensive CS high school course that highlighted the breadth of the field of CS beyond just programming. With the course first offered for AP credit in the 2016-2017 school year, this study explores how this "introductory advanced" CS course impacted high school CS class offerings. Using data from a state-wide survey and the Maryland Longitudinal Data System Center (MLDSC), we found inconsistent impacts with the AP Computer Science Principles introduction. Some schools increased the number of CS courses while other schools decreased CS course offerings. This was counter to our expectation of an increase in CS classes at the high school level across the state. Responses from a teacher survey yielded insight into this unexpected outcome and informed explanations for these changes.

KEYWORDS

High School Computer Science Education; Computer Science Principles; Access; ACM Proceedings

1. INTRODUCTION

In 2012 the College Board, with the help of the National Science Foundation, developed a new Advanced Placement (AP) computer science (CS) course. This course, called Computer Sciences Principles (CSP), was specifically designed to be a broader, more welcoming introduction to the discipline than the programming-focused AP CS courses that have been offered since the early 1980's [2]. While programming is part of the curriculum, CSP also emphasizes creativity and problem solving while placing the discipline of CS in context, discussing the role of CS in global society. This broader framing is intended to encourage student populations that have been historically underrepresented (girls, minorities, lower socioeconomic status, English language learners and students with a disability status) to take CS in high school. The hope was that this introduction would be broadly useful and serve as an entry point for learners to pursue further CS instruction as a college major or career, thereby broadening participation in computing.

A number of AP CSP curricula were designed by different organizations to support the new AP CSP offering. These were first made broadly available to schools in the 2012-13 school year [2]. States and schools were therefore given some time to pilot curriculum before the AP CSP course was officially offered for college credit in the 2016-17 school year.

Using the AP program as a means to broadening participation in a field had never before been attempted. This study tries to understand if and how this effort succeeded by investigating how the AP CSP course impacted the CS high school landscape using the State of Maryland as its focus. More concretely, this paper seeks to answer the following research questions:

How did the introduction of a new AP CS course designed to provide an introductory advanced CS option affect the CS courses offered at the high school level?

How do teachers explain the role of the AP CSP course in the landscape of their school?

The data for this study comes from three distinct sources: state data from the College Board and the Maryland Longitudinal Data System Center (MLDSC) to determine which CS courses

were offered by high schools across the state, and a state-wide survey of CS teachers asking about changes to CS courses at their schools and their understanding of why the changes occurred. These data give us two perspectives on how the introduction of the AP CSP course impacted the landscape of high school CS. We chose these sources to understand how the rollout and adoption of the new AP CSP course, with its unique positioning as an introductory advanced course, is affecting all CS course offerings in the first years of AP CSP exam availability. The goal is to highlight early indications of affordances and unexpected hindrances this new AP course may generate in the overall state landscape of CS education. This understanding can inform educators, administrators and policy makers across the nation tasked with making decisions about what CS courses to offer and if and how to incorporate the AP CSP into existing course offerings. Ultimately, this work will help shed light on one part of the national effort focused on broadening participation in computing.

2. PRIOR WORK

2.1 Computer Science for All

The last decade has seen a significant push to bring computer science to all learners. In the United States, a great deal of progress is due to a concerted funding effort from public and private agencies (e.g. [5, 11]), as well as non-profit organizations (e.g. [14]) focused on giving all learners the opportunity to learn foundational CS ideas. These efforts generally have widespread support from politicians, district leaders, school administration, teachers, students and parents [12]. While much progress has been made, there is still significant work that remains to be done [18, 19]. Initiatives focusing on achieving this lofty goal exist at all levels of the American educational system. This includes countless classroom and school-level initiatives, often led by small groups of committed teachers with the help of local organizations. There are also a growing number of district-level initiatives seeking to bring meaningful CS learning to students across the district, such as those in large urban districts including New York City [8] and Chicago [13], as well as non-urban districts, like the work happening in Broward and Clark Counties [14]. There are also state-wide efforts happening around the United States (e.g. [1, 6]) including an organization sharing best practices [7].

Most recently we are seeing national efforts in the United States that are working towards the goal of CS for all. While there are large scale funding efforts coordinated at the national level, only recently have specific curricular initiatives started looking beyond local and regional impacts toward national roll outs. One example of this can be seen with the Exploring Computer Science (ECS) curriculum [10, 16], which was initially developed and piloted in Southern California, but has since spread to schools across the county (e.g. [15]). A second notable example that our research investigates is the AP CSP course introduced for college credit in the 2016-17 school year. While not a specific course in the same way ECS is a course, AP CSP shares features of a single curricula in that the organization overseeing the program (the

College Board) approved and endorsed only ten curricula providers.

This work builds on the growing body of literature investigating how work at the state level can bring CS to all learners (e.g. [1, 4, 7]). This research is similar to work that has looked at the impact of rolling out new CS curricula, in particular, [3]'s investigation of the introduction of the Exploring Computer Science course in Wisconsin. This work differs in that it is looking at an AP curriculum, which has its own set of features and challenges, while also seeking to gain insight into mechanisms behind the adoption (or avoidance) of the new curriculum.

3. STUDY CONTEXT AND METHODOLOGY

3.1 Computer Science in Maryland

This study focuses on the state of Maryland as a model of the changing CS landscape in the United States. We begin this section by reviewing the state of CS in Maryland before discussing the data sources used in the study. The number of Maryland students taking a CS course has been increasing annually, although the rate of increase is not consistent across gender, race and ethnic subgroups [9]. In the spring of 2018 the Maryland state government pledged 5 million dollars to computing education. This was the culmination of almost a decade of efforts by advocates of CS education, starting in 2011 with grassroots support for addressing problems in Maryland high school computing. These efforts led to an NSF funded statewide assessment of Maryland high school CS teachers in 2012 [6]. The following year NSF funded work led to the development of CS Matters, one of ten CSP curricula endorsed by the College Board. In 2015, Maryland representatives joined the 17 state alliance, Expanding Computing Education Pathways [7].

The State of Maryland has 242 public high schools that are organized into 24 local education agencies (LEAs). Each LEA has curricular discretion allowing them to independently decide which courses are offered and which curriculum will be used for each course. This creates multiple places across the state where decisions are made regarding what CS courses are offered in schools, creating a dynamic environment statewide for computing education. This organizational structure means there is no centralized body that decides what CS courses will be taught across the state, making Maryland a particularly good state to study how a new AP CS course impacts the landscape of CS education as there 24 independent LEAs make decisions about what to teach.

3.2 Data Sources and Methodology

Through partnerships with the college Board and the Maryland Longitudinal Data System Center (MLDSC) we obtained two data sets. The College Board provided data including how many public Maryland high schools offered AP CS A (the pre-existing AP CS course), AP CSP or both during the 2016/17 and 2017/18 school years. In addition, we queried the MLDSC to determine how many high schools had offered the CSP course in the previous three years (2012-13 to 2015-16 school years). This

allowed us to identify schools that were piloting the course before the College Board offered the CSP AP exam.

In addition to College Board and MLDSC data, this paper analyzed data collected through a statewide landscape survey of Maryland public high school teachers. Beginning in 2012, the Maryland Center for Computing Education (MCCE) has conducted an electronic survey in alternating years of teachers and school administrators interested in computing education. The survey is based on the CSTA National Secondary School CS Survey and is distributed to the 1000+ person MCCE Contact Database of CS educators and advocates across the state.

To determine CS teachers' perceptions of CS offerings at their schools two questions were added to the 2018 landscape survey. The questions were designed to inquire about changes in course offerings at teachers' schools in the years just before and just after the AP CSP was officially offered for college credit. The exact wording of the questions was as follows:

Last school year (i.e., between the 2015/16 and 2016/17 school years), did your school make any changes to the computer science courses at your school? (Please indicate if your school had no changes, altered a computer science graduation pathway, added a new course, removed a course, changed the curriculum for a course, etc., and then, describe why you believe the changes occurred.)

This school year (i.e., between the 2016/17 and 2017/18 school years), did your school make any changes to the computer science courses at your school? (Please indicate if your school had no changes, altered a computer science graduation pathway, added a new course, removed a course, changed the curriculum for a course, etc., and then, describe why you believe the changes occurred.)

The 2018 landscape survey collected a total of 94 responses. Respondents represented 69 of the 242 Maryland public high schools and 22 of the 24 Maryland LEAs. Responses were open coded using a grounded theory approach to identify the patterns in changes of school computer science offerings [17]. This produced a set of insights complementary to the MLDSC data, allowing us to understand the changes observed at the system level and provide insight into teachers' overall perceptions of how CS at their school changed during the first two years of the AP CSP course being offered. Five codes related to perceptions regarding the increase of CS offerings in schools were determined.

4. FINDINGS

4.1 Dynamism in State-wide CS

At first glance, the introduction of AP CSP had a negligible impact on the statewide CS landscape. MLDSC data recorded a 3% decrease in Maryland high schools offering any AP CS courses from 2013 to 2018 (Table 1). This result is misleading. When the data is differentiated by course (AP CSP, AP CS A and both AP CSP and AP CS A) a more dynamic picture of a changing CS landscape emerges. AP CSP was rarely taught before the 2016-17 school year. Only 24 high schools in the state (10%) offered an AP CSP course before fall of 2016. This is not surprising, as these were

the piloting years before the formal launch of AP CSP. In the 2016-17 school year, the number of schools that taught only AP CSP and schools that were teaching both AP CSP and AP CS A increased to 12% and 30% respectively. Meanwhile, schools that were only teaching AP CS A decreased from 43% to 9%. Taken together, this demonstrates a high-level impact that the AP CSP course introduction had on schools, and thus students, across a large, decentralized state.

Table 1. Number of AP CS *classes* taught in Maryland high schools and the number of Maryland **high schools** offering those classes from 2013 to 2018.

	Classes in % of total high schools		
	2013-14 to 2015-16	2016-17	2017-18
AP CSP only	7 in 3%	28 in 12%	28 in 12%
AP CSA only	104 in 43%	21 in 9%	15 in 6%
Both AP CSA and AP CSP	34 in 7%	150 in 30%	152 in 31%
All AP CS classes taught	145 in 52%	199 in 51%	195 in 49%
All AP CSP taught	24 in 10%	103 in 43%	104 in 43%

These data also reveal that AP CSP has been adopted quickly. College Board data record a 433% increase in high schools that offered the AP CSP course from 2013 to 2018, growing from 10% of MD high schools to 43% during that time. By the 2017-18 school year, the first year the College Board offered the CSP AP exam, the number of Maryland high schools offering AP CSP had increased to 43% of total schools. In the same period the number of Maryland high schools offering AP CS A decreased from 50% to 38%. Maryland high schools offering any kind of AP CS course decreased slightly (from 52% to 49%) during that same time, likely reflecting schools dropping AP CS A from their annual course offerings. Collectively, this reveals a pattern of schools replacing AP CS A with AP CSP, a pattern with potential implications that we turn to later in this paper.

4. 2 An Increase in CS Courses State-wide

We were also interested in understanding how the introduction of AP CSP changed the CS landscape within schools at the course level. To get some understanding of this, we used the MLDSC and College Board data to extrapolate a minimum number of CS **classes** offered in Maryland schools. We calculated a **minimum estimate** because we have no information on how many sections of a particular course a school might be offering. There are Maryland high schools in which more than one class of AP CSP or AP CS A is offered, which our data do not capture. There are also schools that are offering CS A and CSP courses as non-AP courses, which we have not captured. Working within these limitations (assuming that only one section of every course was taught at every school and every CS A and CSP course was taught as an AP course), we determined that the introduction of

AP CSP increased the overall number of individual AP CS courses offered by Maryland public high schools by at least 27%, from 145 to 195 courses (Table 1). Table one also demonstrates how quickly AP CSP has been adopted in the state, as 104 of the total 195 CS classes offered state-wide (53%) in 2017-18 were AP CSP.

4.3 Dynamism within individual LEAs

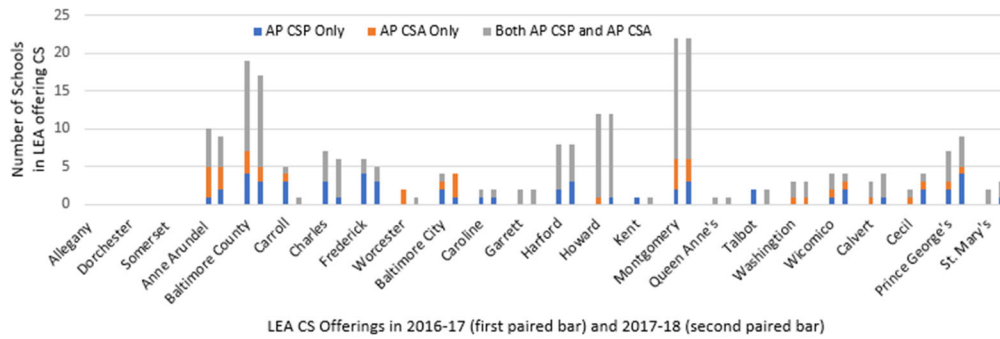Having looked at the state as a whole, we then looked at

Figure 1. Number of schools offering AP CS courses by Maryland LEA

individual LEA data to get as clear a picture as the data allowed to determine where exactly these changes were occurring and to see if we could identify a pattern, specific characteristics or potential explanations for this dynamism. The MLDSC data demonstrates that the complex and dynamic landscape at the state level is also found within LEAs. Between the 2016-17 and 2017-18 school years, this dynamism resulted in a variety of outcomes regarding the number of high schools offering CS courses LEA-wide (Figure 1). The most prevalent situation, found in 11 LEAs, was an equal number of AP CS course additions and subtractions in schools, resulting in no net gain or loss of schools that offered AP CS.
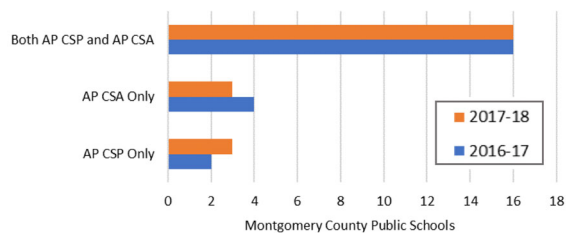

Figure 2. Schools in Montgomery LEA offering AP CS courses.

For example, Montgomery LEA had 22 schools that offered some sort of CS course in 2016-17 and 22 schools that offered some sort of CS course in 2017-18. This stasis masks a drop in the number of schools offering AP CS A and an increase in the number of schools offering AP CSP (Figure 2).

The next most common situation, represented by 6 LEAs, was a combination of school level AP CS course additions and subtractions that resulted in a net decrease in schools offering AP CS courses. These schools also show a dynamic landscape. Anne Arundel LEA increased the number of schools offering only AP

CSP while losing schools that offered just AP CS A or both (Figure 3). Four LEAs had a combination of AP CS course additions and subtractions that resulted in a net increase in schools offering AP CS courses. Three LEAs had no AP CS offerings for either year (Figure 1).

It was hoped that the introduction of AP CSP would enable schools that had not been offering AP CS courses to start doing so. Our analysis indicates that this has generally not been the pattern. Seven LEAs distributed throughout the state had at least one high school that was not offering any AP CS courses add AP CSP over the 2016-17 and 2017-18 school years. We determined that only 11 of the 242 public high schools in the state offered AP CSP as their first ever CS offering. Five LEAs had at least one high school offer a single AP CS course and then added the other course, so that they offered both AP CSP and AP CSA. This was the case for six high schools in the state.
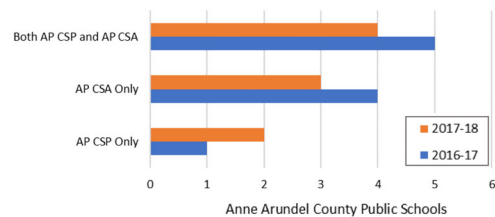

Figure 3. Schools in Anne Arundel LEA offering AP CS courses.

Our analysis also determined that LEAs were dropping CS courses between the 2016-17 and the 2017-18 school years. In four LEAs, a high school offered both AP CSP and AP CS A in the 2016-17 school year but then dropped a CS course in the 2017-18 school year. Three LEAs had high schools that had offered only AP CSP in the 2016-17 school year and dropped the course in the 2017-18 school year, offering no AP CS course. It is possible that this was the case for other schools as well, but because the data we have are aggregated by LEA the situation could be masked by what other schools in the district had done. From our data it is also not possible to determine which AP CS course was dropped when a school stopped teaching both AP CS courses.

4.4 Teacher Perceptions of Changes

To start to understand the mechanisms behind the observed dynamism, we next looked to the MCCE landscape survey data for further insight into changes observed due to the introduction of the AP CSP course. Fifty-five of the ninety-four respondents reported expanding CS programs in their schools. Expansion includes increasing course offerings or recruiting students and increasing enrollment. This is related in the following two

teachers' responses: *"I heavily recruited for next year and will have 3 times the foundations students and a second AP course (AP Computer Science A)"* and *"Began teaching Foundations of Computer Science in 2016-17 with one course. 2017-18 we had two sections of FoCS!"*.

Our analysis identified five reasons AP CSP was adopted in Maryland public high schools.

Reason 1: AP CSP is being used as a (often intermediate) stage in a CS track/pathway

Most commonly in the survey, teachers mention existing introductory CS curricula (e.g. Foundations of CS and Exploring CS) as acting as a lead into AP CSP. In such cases, AP CSP can then serve as a way to prepare learners for AP CS A and a possible capstone project. A feature of this design is this four-course sequence can act as a complete high school CS pathway that covers all four years. Twelve of the 94 respondents mentioned adding a CS course to build a CS pathway of this nature. Ten of these discuss AP CSP as an intermediate course with another respondent framing AP CSP as first in a potential pathways sequence. One respondent described Foundations of CS leading to AP CSA, with no mention of AP CSP.

We can see how the new course shaped emerging CS pathways by looking at year-over-year changes within the same school For example, one teacher gave the following response for the 2016-17 question: *"Yes, added a new course 2016-17 AP CSP for first time was turned into a full-year AP level course (had been offered as semester, non-AP course); - reason: offered nationwide as AP in that year for the first time, school growing a new pathway."* In the subsequent question, asking about the following school year, the teacher wrote: *"yes, added a new course 2017-18 AP CSA offered for first time; - reason: pathway just started, adding one course at a time; also switched curriculum for Foundations of CS course from Exploring CS to CS Discoveries at prompting of district & professional development offered"*

Reason 2: External requirements / CSP now fulfills a graduation requirement

Ten respondents discussed changes in their schools' course offerings during the years surrounding the introduction of AP CSP in terms of graduation requirement. Three specifically mention CSP, 6 discuss Foundations of CS (one person discussed both CSP and Foundations) and 2 discuss general CS. *"We added more foundations of cs and AP CS P courses. This was due to increased enrollment. I believe that the two courses now counting as the tech ed graduation requirement has greatly increased enrollment."* A second, more direct example of this can be seen in the response: *"We added 'AP Computer Science Principles' to align ourselves with county course requirements and to offer an AP course to meet the technology education graduation requirement."*

Reason 3: Content beyond programming more appealing

There were four respondents that discussed the shift from CS courses focusing on programming to a broader view of CS as part of the motivation for introducing AP CSP at their schools. *"Principles of Programming was changed to Foundations of Computer Science to align with curriculum promoted by code.org*

and professional development. It also added more emphasis on a greater range of topics in CS other than just programming." It is important to note that this shift to a broader view of CS was not always viewed positively. *"Programming classes were eliminated (pure code writing which many of my students wish they could do as a CS course) - not as much interest without courses now that are code driven. Students want to learn how to program and those courses are gone."* This latter quote is interesting as it is counter to the larger narrative in CS education circles and the desire to downplay programming and its centrality to the field. This suggests a need for further research to better understand the characteristics of this school and why this might be the case. We will return to this idea later in the discussion section.

Reason 4. AP is compelling to students/ AP adds value to a CS track/pathway

The fact that the new introductory course was an AP course was also mentioned by teachers as a reason for adoption. Of the two respondents who mentioned this, one reported this positively while the other reported it negatively. Viewed positively, one teacher responded: *"Our school has a three course sequence. Last year, we changed the second course from a generic elective called "Programming and Computer Concepts" to AP Computer Science Principles. This was a positive change for enrollment. A lot of high-level students weren't willing to take an unweighted elective in this slot. Now the CS program has two back-to-back AP courses, making it hold sufficiently more value for students. During the prior class, students were doing AP level work, but not getting any credit for it."* At the same time, another teacher saw the opposite outcome, writing *"added sections of Computer Science Principles AP and Java; CSP-AP sections are needed due to more enrollment caused by a push by to take an easy AP course. This is not a good thing; it causes a decrease in enrollment in legitimate course."* Similarly to reason 3, the mixed response from teachers speaks to the complexity and challenges related to introducing a new course with broad goals. Specifically, the suggestion that AP CSP might not be a "legitimate course" reflects larger issues related to perceptions of what "real CS" is and the centrality of programming within the discipline.

Reason 5. CSP allows for more flexibility in a CS track

The final reason that emerged from our analysis was given by a single teacher who cited the increased flexibility that came with the AP CSP course as the reason for adoption. *"Last year we changes AP CS A from a two credit (two period) class to a one credit (one period class.) Reason for this change was the double period restricted the number of students enrolling and with AP CS Principles, do not need two class periods."* This speaks to the quality of the materials associated with the new course and how much care was taken to ensure it could fit within existing educational infrastructure.

5. DISCUSSION

5.1 Shifting Landscape of High School CS

We highlight how the CS landscape in a decentralized state looks profoundly different after the introduction of AP CSP. In the two years since the official introduction of AP CSP, Maryland has

had a 3% drop in the number of schools offering any AP CS courses but a significant increase (from 10% to 43%) in high schools that offered AP CSP. Meanwhile, the number of high schools offering AP CS A has dropped from 50% to 38%. It is likely that dropping AP CS A from school CS offerings is responsible for the statewide drop in CS courses offered. In contrast to the overall state-wide decrease in **schools** offering CS, introduction of AP CSP has increased AP CS **classes** by at least 27%. AP CSP has been quickly adopted and is now the most commonly taught CS class in the state (53% of all CS classes taught are AP CSP).

Examining the school-level LEA data we can determine that the introduction of AP CSP has convinced only 3% of Maryland schools to adopt an AP CS course who had not previously offered AP CS to their students. While any increase is a positive outcome, this suggests the impact of AP CSP was less in the form of introducing CS to schools, and instead, was in one of two ways: changing existing CS courses towards something designed to be more broadly appealing and expanding offerings, thus providing more opportunities for learners to take CS. Some schools have added AP CSP to enhance a preexisting CS curriculum, while others have dropped teaching AP CSP in the 2017-18 school year, so that these schools no longer offer any CS course. Unfortunately, because the College Board and MLDSC data are given at the LEA level, there are still some gaps to be uncovered to fully explain trends.

5.2 Varying Needs of Schools

The diversity of reasons given by teachers for why their respective schools chose to introduce the new AP CSP course is an interesting finding. In some instances, the reasons matched the motivations of the designers of the new course, namely, the desire to have a new course that presents a broader picture of what the field of CS includes and frame the discipline in a way that attracts a broader range of students. Teachers also gave justifications that spoke more to institutional requirements, including the desire to have a fourth course to fill out a full four-year CS or the general desire for a course to bridge the existing introductory course and the more challenging AP CS A course. What is interesting about this second line of motivation is that it is orthogonal to the first motivation (and the motivation of the designers). If a school was looking for a fourth CS course to add, it could have just as easily been a course on physical computing or advanced data analysis as one designed to broaden participation.

These differing motivations highlight features and tensions of the decision to both create the AP CSP course and to use the AP mechanism in the first place. Features result in hundreds of schools across the country introducing a new course focused on broadening participation to learners. Tensions can be seen in the data presented above. First, that there are many instances of AP CSP replacing an existing CS course, which does not expand access. While this may be a positive change, it is easy to imagine instances where the net effect is less than desirable, a fact reflected in some of the comments given by teachers. Secondly, that AP CSP is being used to solve numerous different problems. As a result, there may be places where AP CSP is not the ideal solution but the best or easiest available. This is an artifact of the variety of challenges faced by schools seeking to introduce more CS into the curriculum. The fact that a single AP course is being used to fill very different needs across schools in very different situations speaks to the larger need for more research in the world K-12 CS education, from developing curricula to training teachers and educating decision makers. Additional case-specific solutions need to be developed to meet the specific needs of different states, LEAs, and schools.

5.3 Limitations and Future Work

Part of the value of this work is that it affords a very early snapshot into how AP CSP is being adopted at a state level. Working in almost real time, however, limits our ability to attain a complete picture, as we don't yet have access to data regarding student enrollment or the number of sections of AP CSP that are being offered. Longitudinal data will be needed to understand if what we are reporting is a blip or a lasting trend.

6. CONCLUSION

The goal of this work is to understand how a new, national CS course designed to broaden participation in computing affected the high school CS course landscape. To answer this question, we focused on a single state prior to and immediately after the introduction of the AP CSP exam. There are two main findings from our work.

First, the introduction of AP CSP increased the number of CS courses offered by Maryland public high schools. This change took place mainly in schools that were already offering CS courses, so the AP CSP course appears to have had relatively little impact in terms of bringing CS into schools where historically it had not been taught. In this respect, at a school-level, AP CSP did not broaden participation in CS in schools where CS was not historically offered. That being said, the data also show that the new course is achieving its goals. The number of schools that offered only CS A across the state dropped significantly as they either swapped CSP for CS A or added CSP alongside CS A. Likewise, the data reveal examples of expanding pathways and increased enrollment tied to the AP CSP course, highlighting the successes of the program.

Second, AP CSP was incorporated into schools to fill several different needs. Based on the experiences of teachers from across the state, our analysis revealed several different motivations, including the need for an intermediate course between base introductory courses and the existing AP CS A course and the need of an additional course to fulfill a four-year high school CS pathway.

The analysis and findings presented in this work illustrate the complex landscape and dynamic nature of the constantly-shifting state of CS education in American high schools. Further, this paper highlights the different experiences of individual teachers and schools with respect to trying to meet the growing call for CS for all. While more work remains to be done to fully understand the new emerging landscape of CS in high schools across the country, this analysis begins to tell the story of how and why the new AP CSP is changing the landscape of high school CS.

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